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Disposal of Fluidized-Bed Combustion Ash in an Underground Mine to Control Acid Mine Drainage and Subsidence

**Quarterly Report
February - May 1994**

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June 1994

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**For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia**

**By
National Research Center for Coal and Energy
Morgantown, West Virginia**

MASTER

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Progress Report

for the Quarter of

February 16, 1994 to May 15, 1994

Project - ETD05 "Disposal of Fluidized Bed Combustion Ash in an Underground Mine to Control Acid Mine Drainage and Subsidence"

DE-FC21-94MC29244

During Phase I (first 18 months) the project is segregated into four areas of reporting: A) Grout Formulation, B) Grout Characterization, C) Water Quality Monitoring, D) Subsidence Control & Contaminant Transport. The first component involves formulating a grout mixture with appropriate flowability to be used in filling complex mine voids. The Grout Characterization component will determine the flowability characteristics of the formulated grout. The Water Quality component involves background monitoring of water quality and precipitation at the Phase III (Longridge) mine site.

This report separately discusses progress on all components of the program in order of project subtask. The subtasks are arranged according to the network diagram on the following page.

Project Name: ETD05

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A. Grout Formulation

1.0 Task Description

1.1 Grout Formulation - The purpose of this task is to formulate grout recipes that will be acceptable to use for the filling of complex voids. The recipe will be adjusted as data from other project components is presented regarding flowability and strength requirements.

2.0 Summary of Quarter's Accomplishments and Significant Events

Efforts were made to recruit a graduate research assistant for this project. Contact was made with a former WVU Civil Engineering student who was employed by an oil well drilling and logging company. This individual had field experience with injection of grout into deep cavities under conditions of high temperature and pressure; consequently it was believed that he could bring useful experience to the project. Negotiations were successful and it is anticipated that Mr. Aaron Kitzmiller will join the project as a graduate research assistant in early June, 1994.

Other significant events: Participated in monthly organizational Meetings held at NRCCE and kickoff meeting at DOE/METC on May 3, 1994. Also made plans, selected, and submitted requisition for medium-capacity mortar mixer. The mixer, noted and provided for in the project proposal, will facilitate the preparation of grout mixtures in the laboratory.

Ash samples from MEA arrived and preliminary sieve and hydrometer tests were performed to assess particle sizes and size distributions. Literature relevant to the project was also collected and reviewed during this quarter.

3.0 To Date Accomplishments

As noted above.

4.0 Technical Progress Report

Results of preliminary tests indicate that the fly ash portion of the MEA residue contains silt-size particles while the bottom ash fraction is relatively coarse with a maximum particle size in excess of 3/8 inch. The rather large-size particles may make the combined MEA ash difficult to work with in the field in terms of maintaining grout coherency and attaining a non-segregating mixture.

5.0 Plans for Next Quarter

- 5.1 Initiate grout mixing in the laboratory to assess relationships between water content, strength, and consistency.
- 5.2 Initiate testing to assess impact of water quality on grout characteristics.

5.3 Continue literature review.

B. Grout Characterization

1.0 Task Description

Task 2.1.1 Literature Search - This task will involve both manual and computer searches of the literature on several topics. This task will insure that the latest advances in grout technology are incorporated into this project and that no effort is wasted in duplication of results.

Task 2.1.2 Grout Characterization - In this task, appropriate viscometric tests will be conducted to determine the relationship between stress and rate of strain as a function of time and grout composition.

Task 2.1.3 Analytical Modelling - This task is the development of an analytical model to describe the rheology of the grout. This task will provide a constitutive relation that describes the behavior of the grout in agreement with the laboratory results.

Task 2.1.4 Numerical Modelling - This task includes the adaption of commercially available fluid modelling software to incorporate the rheological model developed in Task 1.3. This task will enable the placement of grout to be modelled numerically.

2.0 Summary of Quarter's Accomplishments & Significant Events

Literature Search - 80% complete
Grout Characterization - 5% complete
Analytical Modelling - 10% complete
Numerical Modelling - 2% complete

Attending Kickoff Meeting at DOE/METC on May 3, 1994. Also attended monthly project meetings to discuss progress and issues with other members of research team.

3.0 To Date Accomplishments

No tasks completed 100% to date.

4.0 Technical Progress Report

Task 2.1.1 Literature Review - A careful review of previous scientific progress has been initiated. A comprehensive literature search has been performed on the COMPENDEX database at the WVU library, the WVU library card catalog, and the database available through METC. The investigation focused on non-Newtonian rheology, rheology of fly ash grouts, measurement of non-Newtonian fluid properties, and advances in analytical and numerical solutions of flows of non-Newtonian fluids within the past ten years. The WVU inter-library loan system is being used to locate references that may be useful.

2.1.2 Grout Characterization - Samples of the FBC ash have been obtained from both Patriot Mining disposal site in Osage, WV and MEA Power Plant in Morgantown, WV. The ash particles have been examined under an optical microscope and compared to photographs of the ash particles under magnification of a scanning electron microscope. Qualitative tests have been performed with the ash and water. A flowcone has been obtained to acquire quantitative results.

Permission has been obtained from Dr. R. Gupta (Dept. of Chemical Engineering) to use the INSTRON 1011 testing system. This electro-mechanical instrument is being used as a parallel plate rheometer. Aluminum disks, 7 cm. in diameter, have been manufactured to fit the instrument. Acquisition of a gauge to measure the plate separation is currently being investigated. Testing has been performed on toothpaste to become familiar with the instrument's operation and output, and to evaluate the instrument's capabilities. Output data from the machine is recorded by a strip-chart recorder. A sample output plot of force vs. plate separation is attached.

A simple method for evaluating the yield stress of the grout material has been proposed based upon information revealed in the literature search. this method is based upon flow of a yield stress fluid in a pipe. A decision has not yet been made as to the practicality of this approach.

2.1.3 Analytical Modelling - Preliminary development of a general three dimensional constitutive relation has been started, based upon the assumption that the grout material will behave as a power-law fluid with a yield stress. Comparisons with previous forms of constitutive relations for such fluids, as well as applying the principles of continuum mechanics, have yielded a general result for the stress tensor:

$$\sigma_{ij} = -p\delta_{ij} + \left(\frac{\tau_y}{\gamma} + K\gamma^{n-1} \right) \left(\frac{\partial v_i}{\partial x_j} + \frac{\partial v_j}{\partial x_i} \right)$$

where:

σ_{ij} = stress tensor

p = the pressure

τ_y = the yield stress

γ = the magnitude of strain rate

K, n = material properties

This general result will be modified to match future experimental observations.

2.1.4 Numerical Model - The capabilities and cost of commercially available CFD codes have been evaluated. It has been determined that the software package PHOENICS will be used for modeling the non-Newtonian fluid flows of this project. The software license has been purchased, however, the software has not yet been received from the vendor. A truncated demonstration version has been obtained, and preliminary tests are being performed. The purchase of this software package includes admission to a five day training course in Atlanta. Reservations have been made to attend this instructional seminar during the week of June 6-10.

The PHOENICS software code requires a high performance PC platform on which to operate. Hardware from several computer manufacturers were compared, and it was determined that GATEWAY 2000 provided the best machine. A PC with a 90MHz Pentium processor, 16 MB RAM, 540 MB HD, and 17" high resolution screen has been purchased from GATEWAY 2000. The demo version of PHOENICS has been installed on the PC and the speed of operation has been outstanding. No complications are expected when the complete version of PHOENICS arrives.

5.0 Plans for Next Quarter

5.1 Continue with model development and grout characterization. no obstacles are seen in near future to halt progress.

C. Water Quality Monitoring

1.0 Task Description

Task 4.0 Water Quality Monitoring - This task will monitor the baseline water quality of the acid mine drainage from the Longridge and Fairfax mines prior to grouting. A flow monitoring and sampling system will be set up at the Longridge Mine and a precipitation monitoring station will be established between the two mines.

2.0 Summary of Quarter's Accomplishments & Significant Events

Participated in a project meeting at Dept. of Energy/ METC on May 3, 1994. Also accomplished was evaluation and initiation of procurement of equipment for sampling and monitoring of flow and precipitation. An hourly student was located to work on the project.

3.0 To Date Accomplishments

Since the project has began this quarter, accomplishments to date are as noted above.

4.0 Technical Progress Report

The technical progress report is attached.

5.0 Plans for Next Quarter

- 5.1 Modify the site to prepare for installation of the sampling station. After site has been modified and power has been installed, the sampling station and will be installed and calibrated. Sampling will begin in July.
- 5.2 Unresolved issues: There are no unresolved issues during this reporting period.
- 5.3 Schedule: The Water Quality Monitoring Task is on schedule.

C. 4.0 Technical Progress Report: Water Quality Monitoring

A joint water quality and flowing monitoring station will be established at the Longridge site to carry out baseline water quality monitoring in Phase I. In addition, a precipitation recording station will be set up. The stations will continue to be utilized during Phases II and III too evaluate changes in water quality and quantity after grout injection. As described below, flow monitoring and sampling needs were evaluated and the systems selected.

Design of Monitoring Systems and Selection of Equipment

Flow Monitoring

The only historical flow data available from the Longridge Mine was taken during January and June 1982. During that period, flow was measured to range from 14,400 to 106,000 gallons per day (10 to 74 gpm). Since no recent data on flow is available, it is important that the system chosen be capable of measuring a wide range of flow. The flow measurement system chosen for the Longridge Mine consists of a variable gate open channel flow meter which will be placed in a 6 inch pipe. Water leaving the mine will be directed to the 6 inch pipe placed on a slope of about 0.5 to 1.0%. Calculations show that the system will be able to measure flows of between 0.25 to 180 gpm which should readily cover the range of flows expected. Flow data from the meter will be continuously recorded and will be sent to the sampler described below in order to take flow proportional sample. Currently, flow exits the mine through a single opening approximately 10 feet in width. The area near the opening will be regarded so as to capture all the flow in a trench which culminates in the 6 inch pipe. Flow data will be stored on flowlink software and downloaded weekly to a portable computer for transfer to a desktop computer at WVU.

Selection of Sampler

Samples of minewater from the Longridge Mine will be collected using a weatherproof sampling station (heated and cooled). all samples will be collected in polyurethane containers. Flow proportional samples will be taken based on a signal from the flow meter. The sampling

station will be visited once per week for collection of samples.

The sampler selected is a refrigerated model which can be programmed to take samples in a sequential or a composite mode. It is planned to initially program the sampler to take 1112 samples daily (every two hours) and composite over a period of one week. This will allow the weekly composite sample to reflect water quality over the entire week's period and permit a good estimation of the actual mass of contaminants in the acid mine drainage (AMD) for that period. It is recognized that there may be some change in the sample due to exposure to oxygen over the week's time in the composite. However, since the pH of the samples is typically below 3.0 and the sampling chamber will be refrigerated (4° C), it is expected that any changes will be relatively minor. In order to determine whether significant changes in water quality are occurring during the storage period, grab samples will be taken and an aliquot analyzed immediately. The rest of the sample will be stored for a week and reanalyzed. If it is found that significant changes are occurring during storage, the sampler will be reprogrammed to take samples for a two day period just prior to collection. During each weekly sample pickup, the samples will be placed in a cooler and transported immediately to the WVU laboratory for analysis.

Baseline water quality samples will also be taken from the active Fairfax Mine in Phase I prior to grouting. Since only a small portion of the mine will be involved, it is not expected that a major effect on water quality will occur as a result of the grouting. However, it is planned to sample water quality before and after grouting in this mine also to evaluate potential changes in AMD quality. All water in the mine is currently collected in a sump and is pumped out of the mine as required. Baseline water quality data will be developed by taking grab samples of the pumped flow twice a month until grouting begins. When grouting begins, it is planned that sampling frequency will be increased so as to sample each week. Weekly sampling will be continued for a period of three months after grouting is complete, or until it is determined whether significant changes in water quality have resulted from the grouting. If analysis of the data shows no significant changes in water quality after grouting, sampling frequency will be reduced to monthly and continued for approximately three years.

Monitoring of Precipitation

It is anticipated that the amount of precipitation in a given time period will effect the volume of water moving through the mines and that strength of the AMD and flow will have an inverse correlation. Precipitation events in the vicinity of the test mines will therefore be measured so as to note any correlation between AMD strength, flow, and precipitation events.

A battery operated tipping bucket type of rain gauge was chosen for precipitation measurement. It will be located in an appropriate location between the two mines in a setting away from trees and wind currents. Precipitation events will be continuously recorded on a data logger. The gauge will be visited weekly by the student worker who picks up the water samples and the data downloaded to a portable computer for transfer to a desktop computer at the office.

Procurement of Equipment

Specifications for the sampler, flow meter and rain gauge have been prepared and bids have been requested from vendors by the University Purchasing Office. It is anticipated that bids will be received and the equipment procured by the end of June 1994.

Miscellaneous Project Activity

A student has been located to work on the project. He will begin work when the equipment arrives and the site is ready for equipment setup. Anker Energy has been contacted to arrange to have power run to the Longridge Site for the sampler and flowmeter. Personnel from Anker Energy are currently working with the Power Company and are waiting for a date regarding installation of the line.

D. Subsidence Control & Contaminant Transport

1.0 Task Description

No tasks have been initiated.

2.0 Summary of Quarter's Accomplishments & Significant Events

Effort was made to recruit a graduate research assistant to work on this project. It is anticipated that a student will begin work on this project in the Fall Semester.

Attended Kickoff Meeting at DOE/METC on May 3, 1994. Also attended monthly project meetings to discuss progress and issues with other members of research team.

3.0 To Date Accomplishments

Initiated collection of literature relevant to project.

4.0 Technical Progress Report

Participated in technical discussions on different aspects of project.

5.0 Plans for Next Quarter

- 5.1 Recruit research assistants for the project.
- 5.2 Obtain mine maps, geologic details, etc. on Phase II and III sites, initiate project work and perform preliminary calculations.
- 5.3 Continue literature review and technical evaluations.

Gantt Chart

Gantt Chart

DATE

FILMED

10/18/94

END